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CHIP CARRIER USED FOR SEMICONDUCTOR  
OPTICAL DEVICE, OPTICAL MODULE, AND  
OPTICAL TRANSMITTER AND RECEIVER

This application relates to Japanese Patent Application No. 2003-432013 filed on December 26, 2003, the entire disclosure of which is incorporated herein by reference.

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a chip carrier incorporating an optical semiconductor device or the like mounted thereon, an optical module using  
10 this chip carrier, and an optical transceiver.

Description of the Related Art

In general, an optical module is formed by incorporating a chip carrier on which an optical semiconductor device or the like such as a  
15 semiconductor laser diode (hereinafter, referred to as an LD) is mounted by soldering those onto a package including a power supply terminal, an input signal terminal, a ground terminal, an optical output fiber connector terminal and the like. As the chip carrier,  
20 there is used a dielectric material or a semiconductor substrate. The optical semiconductor device is mounted

on a ground metal-coated portion, by soldering, formed on the surface of the dielectric material or semiconductor substrate, and the optical semiconductor device is then connected with a high-frequency  
5 transmission line or the like formed on the same substrate surface through wire-bonding.

With increase of operating speed in relation to the optical semiconductor device in recent years, excellent high-frequency characteristics have also been  
10 demanded with respect to the chip carrier. As a structural example of the chip carrier aiming at an improvement in the high-frequency characteristics, JP-A-10-275957 discloses a structure in which a conductive substrate having an optical semiconductor device  
15 mounted thereon is incorporated with a dielectric material or a semiconductor substrate having a high-frequency transmission line and a terminating resistor arranged thereon.

In an ordinary chip carrier using only a  
20 dielectric material or a semiconductor substrate, excellent characteristics are hard to be obtained in a high-frequency domain of 20 GHz or above.

Further, in such a chip carrier in which the conductive substrate and high-frequency transmission  
25 substrate are separately provided as disclosed in JP-A-10-275957, although high-frequency characteristics are relatively good, there is a problem that its manufacturing cost is high because of its structure,

and a packaging process requires much time.

#### SUMMARY OF THE INVENTION

It is an object of the present invention to provide a chip carrier that is superior in the high-  
5 frequency characteristics and has a low cost, an optical module incorporating this chip carrier assembled therein, and an optical transceiver.

To achieve this object, reduction of an inductance on the chip carrier is a dominant means.  
10 That is, a high-frequency transmission line and a ground metal-coated portion are arranged on a dielectric material or a semiconductor substrate, a rear surface of which is coated with a metal; the metal-coated portion on the front surface are  
15 electrically connected with the metal-coated portion on the rear surface through a metallic via-hole; a part or all of a side surface of the chip carrier is coated with a metal; and the metal-coated portion on the front surface of the dielectric material or the semiconductor  
20 substrate is electrically connected with the metal-coated portion on the rear surface.

Furthermore, as another means for reducing an inductance of the chip carrier, the reduction of distance between the optical semiconductor device  
25 mounted on the chip carrier and the via-hole of the chip carrier is also prevailing means. In the present invention, when distance between the positions of the

optical semiconductor device and the via-hole is relatively close in minimum, that is, the via-hole is arranged directly below the optical semiconductor device.

5               Thereby, using the chip carrier according to the present invention does not deteriorate the frequency characteristics of optical semiconductor device operating at a high speed. Furthermore, the chip carrier in low cost, an optical module  
10 incorporating the chip carrier and an optical transceiver are realized.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken  
15 in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are plane and side views illustrating a chip carrier structure according to the present invention;

20               FIGS. 2A and 2B are diagrams illustrating characteristics obtained by the chip carrier according to the present invention;

FIG. 3 is a diagram showing an equivalent circuit of the chip carrier according to the present  
25 invention;

FIG. 4 is a plane view illustrating a chip carrier structure according to the present invention;

FIG. 5 is a diagram illustrating characteristics obtained by the chip carrier according to the present invention;

FIG. 6 is a diagram illustrating an LD module structure according to the present invention;

FIG. 7 is a diagram illustrating characteristics obtained by the LD module according to the present invention;

FIG. 8 is a plane view illustrating a chip carrier structure according to the present invention; and

FIG. 9 is a diagram illustrating characteristics obtained by the chip carrier according to the present invention.

## 15 DETAILED DESCRIPTION OF THE EMBODIMENTS

Embodiments according to the present invention will be described in detail hereinafter.  
[Embodiment 1]

FIGS. 1A and 1B show an upper surface and a side surface of a chip carrier 100 in a first embodiment according to the present invention. The chip carrier 100 uses a substrate 101 comprising a dielectric material such as alumina (AlN) or a semiconductor formed of silicon (Si). The following elements are then formed on the substrate: a high-frequency transmission line 102; a ground metal-coated portion 103 on which an optical semiconductor device is

mounted; and a terminating resistor 104. The optical semiconductor device 110 is soldered on the ground metal-coated portion 103. In this embodiment, a description will be given on the assumption that an  
5 external modulator integrated laser incorporating a semiconductor laser 111 and an external modulator 112 is used as the optical semiconductor device 110.

In this embodiment, the high-frequency transmission line 102 is a micro-strip line, and the  
10 ground metal-coated portion 103 is electrically connected with a metal-coated portion on a rear surface through a via-hole 105.

It is noted that reference numeral 106 denotes a lead wire connected to a direct-current power  
15 source; 107, a lead wire connected the micro-strip line with the external modulator 112; and 108, a lead wire connecting the external modulator 112 with a high-frequency line connected to the terminating resistor 104.

20 In the present invention, a part (120) or all side surfaces of the substrate 101 is coated with a metal, and a metal-coated portion 103 on the front surface of the substrate is electrically connected with a metal-coated portion on the rear surface of the same  
25 in order to enhance the ground. It is noted that coating with a metal on a side surface 150 placed at a position closest to a modulator 112 directly concerning a high-frequency operation is most effective, among

four side surfaces 150 to 153 of such a chip carrier as shown in FIG. 4.

In order to confirm an effect of the present invention, FIG. 2A shows optical response characteristics obtained by an actual device mounted on the chip carrier (in a case where the side surface 150 is entirely coated with a metal) according to this embodiment. It is noted that the optical response means a ratio of an output light intensity relative to a high-frequency signal intensity input to the modulator. For the purpose of comparison, FIG. 2B shows characteristics obtained when the side surface is not coated with a metal.

When the side surface is not coated with a metal (FIG. 2B), the characteristics are abruptly deteriorated in the vicinity of 35 GHz, and a resonance is also produced. On the contrary, when the side surface 150 is entirely coated with a metal (FIG. 2A), an abrupt deterioration in the characteristics and the resonance do not occur, and the optical response of -3 dB is obtained even in the vicinity of 40 GHz, realizing the excellent high-frequency characteristics.

FIG. 3 shows an equivalent circuit when the external modulation type laser is mounted on the chip carrier. Here, reference numeral 301 denotes a characteristics impedance of the high-frequency transmission line 102, i.e., 50  $\Omega$ ; 309, a resistance  $R_t$  of the terminating resistor 104, i.e., 50  $\Omega$ ; 302, an

inductance L1 of a bonding wire 108; 303, an inductance  
L2 of a bonding wire 109; 304, an internal resistance  
Rm of the modulator 112; 305, a parasite capacitance Cm  
of the modulator 112; 306, a resistance Rc of the chip  
5 carrier 100; 307, a capacitance Cc of the chip carrier  
100; and 308, an inductance Lc of the chip carrier 100.

It is noted that a laser 111 of the external  
modulator integrated laser is of a direct-current drive  
type, and the equivalent circuit of the laser portion  
10 can be ignored in analysis of the high-frequency  
characteristics. Therefore, FIG. 3 shows only the  
modulator portion in the equivalent circuit.

The abrupt deterioration in characteristics  
or the resonance in the vicinity of 35 GHz observed in  
15 FIG. 2B is caused by a series resonance due to the  
parasite capacitance Cm of the modulator 112 and the  
inductance Lc of the chip carrier 100. Here, a  
resonance frequency fr is given by the following  
expression.

$$f_r = \frac{1}{2\pi\sqrt{L_c \cdot C_m}}$$

20 In order to improve the characteristics by  
shifting this series resonance frequency to the high-  
frequency side, the parasite capacitance Cm of the  
modulator must be reduced or the inductance Lc of the  
chip carrier must be decreased. However, the  
25 capacitance reduction of the modulator may possibly



occur deterioration in device characteristics such as a drop in an extinction ratio that is a ratio of ON/OFF of light beams. Therefore, it can be considered that the inductance reduction of the chip carrier is

5 dominant means.

In the structure of FIG. 1, the inductance  $L_c$  of the chip carrier is reduced by coating with the metal on the side surface of the chip carrier and enhancing the ground, sufficiently increasing the  
10 series resonance frequency. For this reason, it can be considered that the excellent optical response characteristics is obtained without such an abrupt deterioration in characteristics or a resonance as shown in FIG. 2A.

15 It is noted that the characteristics differs depending on the area of the side surface coated with the metal. FIG. 5 shows a simulation result of frequency characteristics (transmission characteristics) when  $1/10$ ,  $1/5$ ,  $1/3$ ,  $1/2$  and all of a  
20 superficial content of the side surface 150 is coated in cases where the side surface 150 of the chip carrier which is closest to the modulator portion 121 is coated with a metal.

It can be understood from the simulation  
25 result of FIG. 5 that the frequency characteristics are improved by increasing a metal-coated area. In particular, in a domain of 40 GHz or above, it can be revealed that the characteristics substantially

equivalent to those, when the entire surface is coated with a metal, can be obtained by setting the metal-coated area to 1/3 or above.

FIG. 6 is a structural diagram of an LD module 600 incorporating the chip carrier according to this embodiment. A high-frequency signal 630 is supplied from the outside to the optical semiconductor device 110 on the chip carrier 100 through a relay substrate 602. Likewise, a direct-current power 640 for driving the optical semiconductor device 110 is supplied through a relay substrate 603. Laser beams 610 from the optical semiconductor device 110 are condensed by a condenser lens 601, and transmitted to an optical transmission fiber 620 connected to the outside. Moreover, in order to monitor an optical output state of the optical semiconductor device 110, a monitor photodiode 604 is mounted.

FIG. 7 shows optical response characteristics obtained from an actual device when the side surface of chip carrier 100 is coated with a metal in the LD module depicted in FIG. 6. It is noted that the side surface of the optical semiconductor device 110 closest to the modulator 112 is entirely coated with a metal. For a purpose of comparison, optical response characteristics of the LD module incorporating a chip carrier, the side surface of which is not coated with the metal mounted thereon are also shown. It was ensured from this evaluation result that coating the

side surface of the chip carrier results in an improvement of the optical response characteristics by approximately 10 GHz.

As described above, according to this  
5 embodiment, simply coating the side surface of inexpensive conventional chip carrier constituted of the dielectric material or semiconductor substrate with the metal can obtain the excellent frequency characteristics without the abrupt deterioration in the  
10 characteristics, and it is possible to provide the chip carrier which is inexpensive, has easy operating steps and is superior in frequency characteristics, the optical module using this chip carrier, and the transceiver.

15 It is noted that the description has been given as to the case using the external modulator integrated laser as the optical semiconductor device in this embodiment, the same effect can also be expected even if the direct-modulated laser having no external  
20 modulator is used. In this case, the side surface closest to the position of chip carrier on which the directed-modulated laser is mounted is coated with the metal.

The present invention is not restricted to  
25 shapes or properties of constituent components on the chip carrier. For example, although the high-frequency transmission line is a micro-strip line in this embodiment, the respective similar effects can be

demonstrated in case of a line (generally, a line of 50  $\Omega$ ) which does not attenuate a high-frequency signal such as a coplanar line or a grounded coplanar line (coplanar line having a rear surface of the substrate  
5 coated with a metal).

[Embodiment 2]

It has been apparent from the foregoing embodiment that reducing an inductance of the chip carrier is important in order to improve the high-  
10 frequency characteristics of the chip carrier. Here, there can be considered the reduction of distance between the modulator 112 of the external modulator integrated laser 110 mounted on the chip carrier and the via-hole of the chip carrier as another means for  
15 reducing the inductance. In order to reduce this distance to the minimum level, it is good enough to arrange the via-hole 105A directly below the modulator 112 as shown in FIG. 8. Reference numerals excluding the via-hole 105A denote structures identical to those  
20 described in conjunction with FIG. 1A.

FIG. 9 shows a simulation result of frequency characteristics when the via-hole 105A is arranged directly below the modulator 112 depicted in FIG. 8. As compared with the example in which the side surface  
25 of chip carrier is coated with the metal described in conjunction with the first embodiment, it is apparent that the excellent characteristics that a resonance does not occur in a high-frequency domain can be

obtained.

However, the flatness of a via-hole portion and the dielectric material or the semiconductor substrate around this portion may be deteriorated which  
5 results in reducing adhesive property at the time of soldering the device by arranging the via-hole directly below the device in some cases. Additionally, there is possibility that stress may be applied to the optical semiconductor device due to a different thermal  
10 expansion coefficient between the via-hole portion and the substrate and thereby the reliability of the device may not be guaranteed. Therefore, a countermeasure against these deteriorations, e.g., reinforcement of soldering is additionally applied according to needs.

15 As described above, according to this embodiment, in the inexpensive conventional chip carrier comprising the dielectric material or semiconductor substrate, since the excellent frequency characteristics without the abrupt deterioration or  
20 resonance in characteristics can be obtained by simply changing the position of via-hole thereof, it is possible to provide a chip carrier which is inexpensive, has easy operating steps and is superior in frequency characteristics, the optical module using  
25 this chip carrier, and the optical transceiver. This embodiment is not restricted to shapes or properties of constituent components on the chip carrier like the first embodiment.

Moreover, a further improvement in the high-frequency characteristics can be expected by conformation in which the first embodiment is combined with this embodiment, i.e., coating the side surface of  
5 chip carrier with the metal and providing the via-hole directly below the optical semiconductor device which is operated with a high frequency.

It is noted that the description has been given as to the example in which the external modulator  
10 integrated laser is used as the optical semiconductor device in this embodiment, but the same effect can be expected even if a direct-modulated laser having no external modulator is used. In such a case, the via-hole is arranged directly below a position of the chip  
15 carrier at which the direct-modulated laser is mounted.

Although a light emitting device has been described in both the first embodiment and the second embodiment, the present invention is not restricted thereto, and it is also effective to a chip carrier of  
20 a detector such as a photo diode (PD) or an avalanche photo diode (APD), an optical module using this chip carrier, and a PD receiver.

It is also effective to an optical transceiver which both the LD module and the PD module  
25 mentioned above are incorporated in the same package.

Further, the chip carrier according to the present invention is not restricted to the optical semiconductor device. An improvement in high-frequency

characteristics can be expected by using the chip carrier according to the present invention as long as it is a device in which a factor deteriorating high-frequency characteristics is caused by a parasite  
5 capacitance of the device, i.e., a capacitive device having a capacitor structure such as a transistor.

It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the  
10 invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.